Current Challenges in the Outer Heliosphere – some recent results from SHIELD DSC

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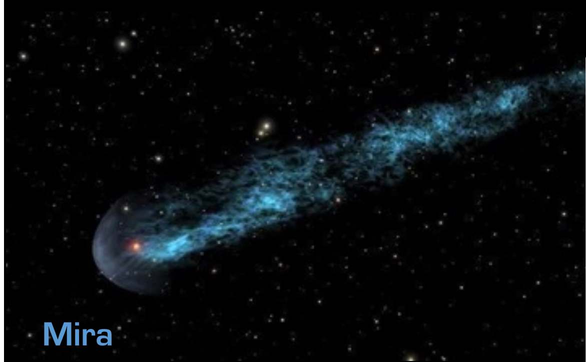
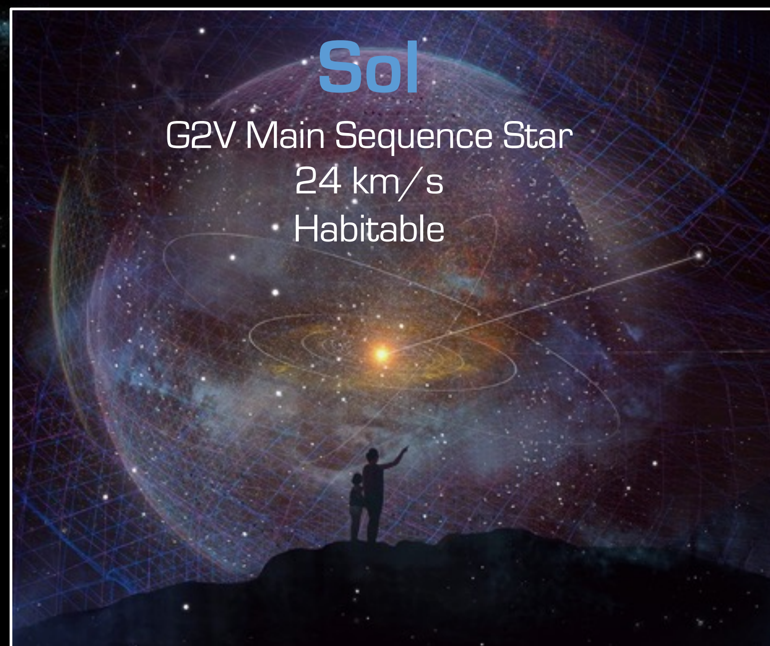
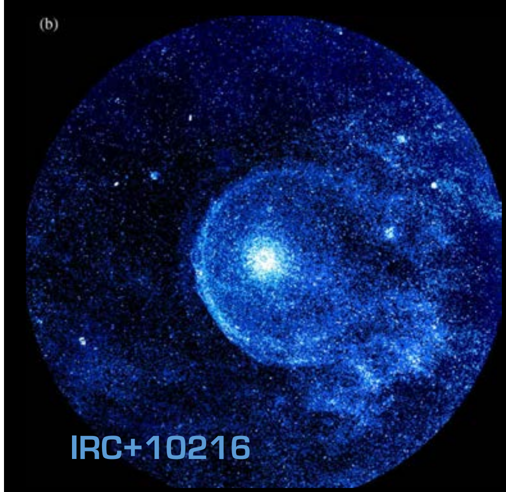
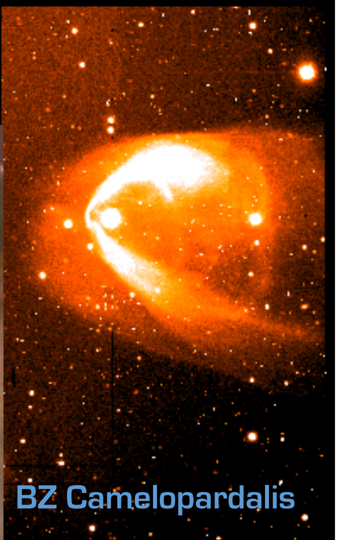
John Richardson (PM)

Heliosphere: the only known habitable Astrosphere



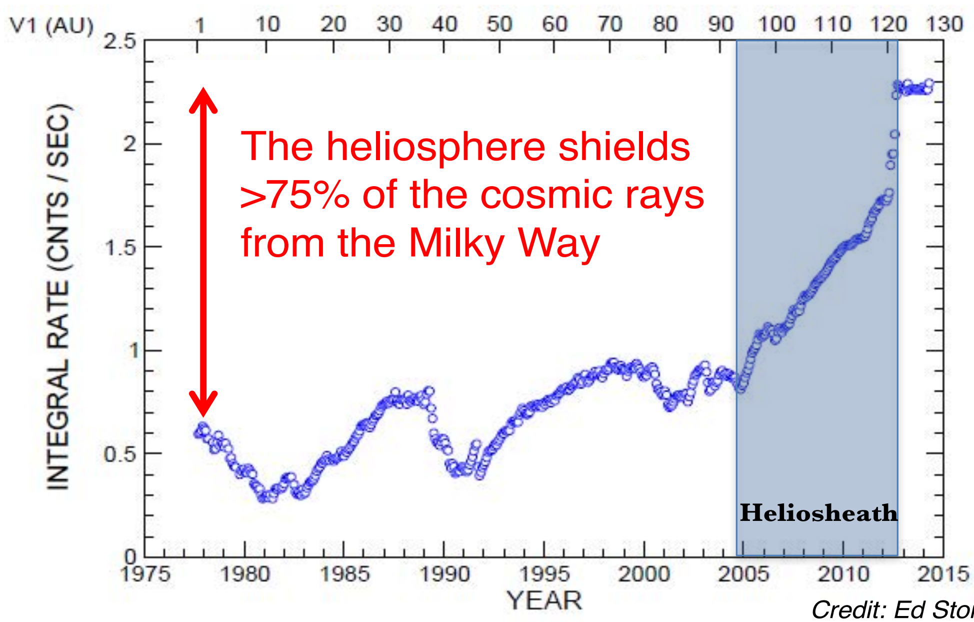






The Heliosphere is an immense shield that protects the solar system from harsh galactic radiation. This radiation affects not only life on Earth, but human space exploration as well

Cosmic Ray measurements at Voyager 1



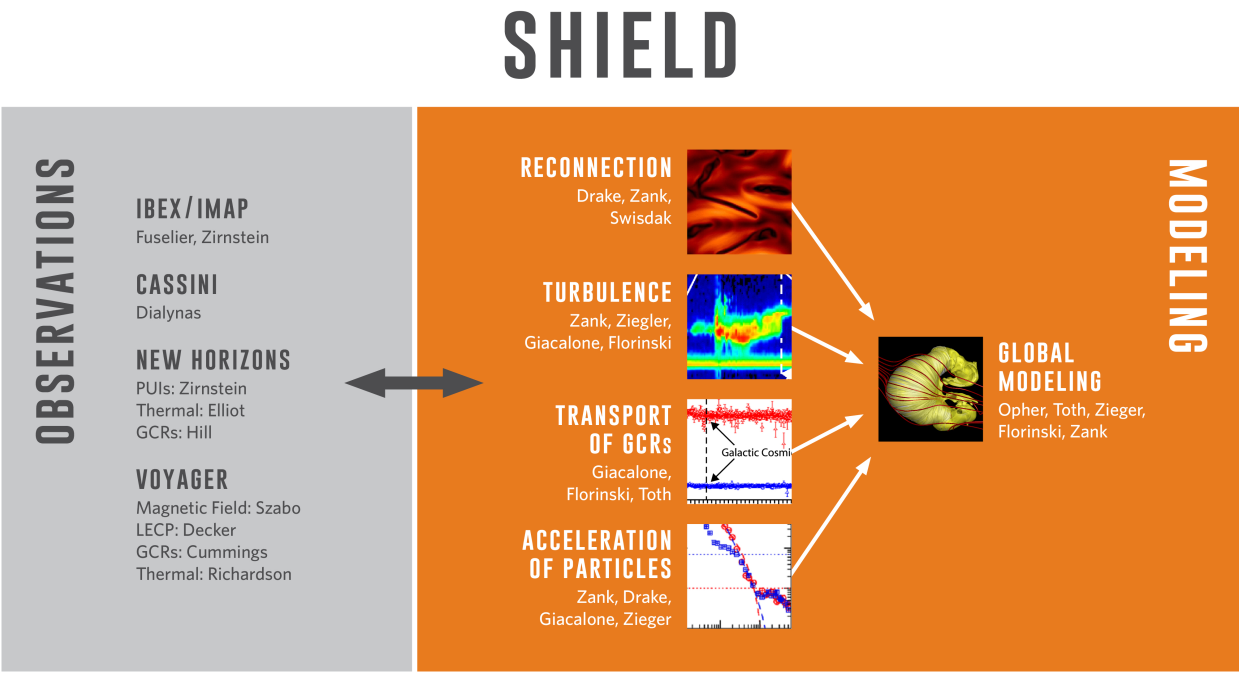
Credit: Ed Stone

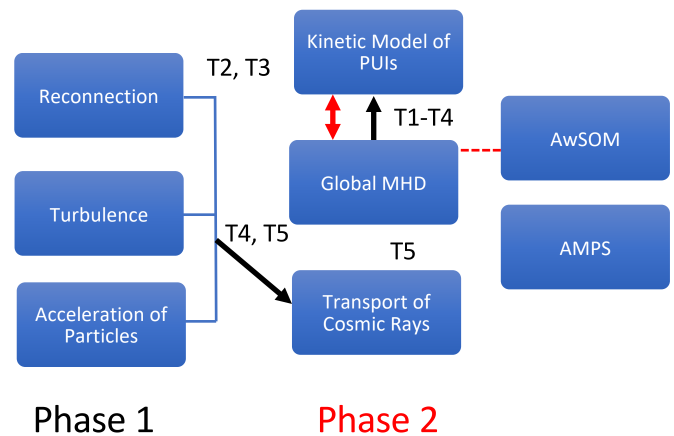
SHIELD's VISION :

The vision of SHIELD (Solar wind with Hydrogen Ion charge Exchange and Large-Scale Dynamics) is to Understand Our Heliospheric Shield laying the Groundwork to predict Habitable Solar Like and M-Dwarf Astrospheres and Cosmic Radiation enabling future Human Exploration to Mars

SHIELD goal is to create a predictive model of the heliosphere and uses a combination of observations, theory, localized kinetic and MHD models to achieve this goal.

http://sites.bu.edu/shield-drive/


SHIELD
OBSERVATIONS
IBEX/IMAP
Fuselier, Zirnstein
CASSINI
Dialynas
NEW HORIZONS
PUIs: Zirnstein
Thermal: Elliot
GCRs: Hill
VOYAGER
Magnetic Field: Szabo
LECP: Decker
GCRs: Cummings
Thermal: Richardson
RECONNECTION
Drake, Zank, Swisdak
TURBULENCE
Zank, Ziegler, Giacalone, Florinski
TRANSPORT OF GCRs
Giacalone, Florinski, Toth
ACCELERATION OF PARTICLES
Zank, Drake, Giacalone, Zieger
GLOBAL MODELING
Opher, Toth, Zieger, Florinski, Zank
MODELING


Reconnection
Turbulence
Acceleration of Particles
T2, T3
T4, T5
Kinetic Model of PUIs
T1-T4
Global MHD
T5
Transport of Cosmic Rays
AwSOM
AMPS
Phase 1
Phase 2

The Science Team: more are joining as SHIELD activities grow

Collaborators:

SHIELD

SHIELD Science Questions

- Science Question A:

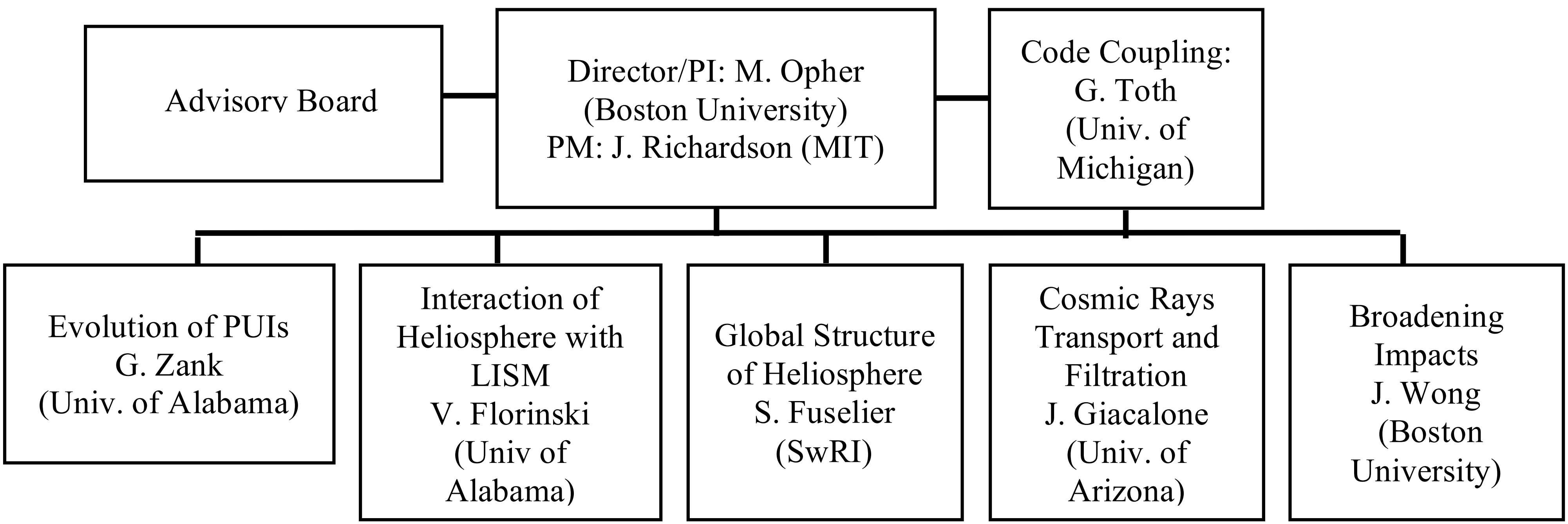
  What is the global structure of the heliosphere?
- Science Question B:

  How do Pick-Up Ions evolve from “cradle to grave”?
- Science Question C:

  How does the heliosphere interact with and influence the interstellar medium (ISM)?
- Science Question D:

  How do cosmic rays get filtered by and transported through the heliosphere

Overall Center Structure

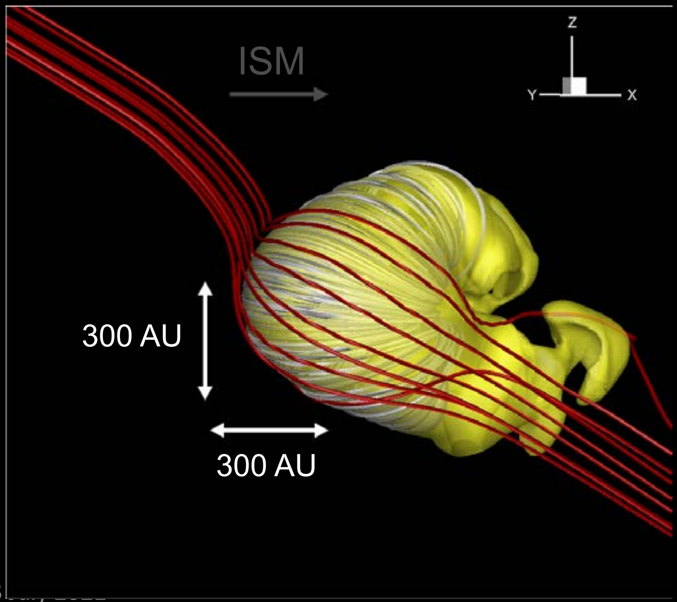


Science Question A:
What is the global structure of the heliosphere?

Models predict a much thicker heliosheath than observations

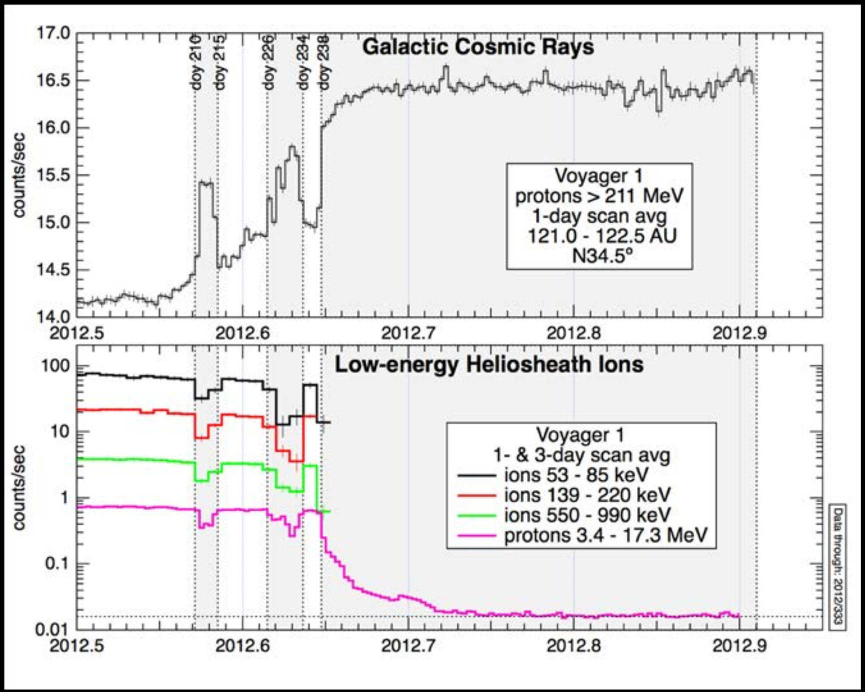
Models predict 60-70AU while thickness was 28AU at V1 and 35AU at V2

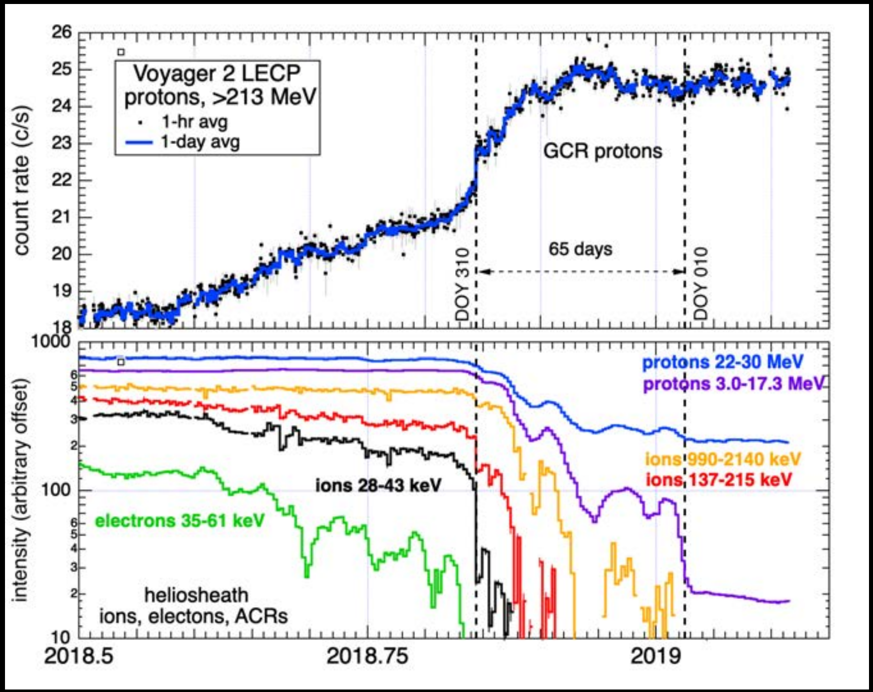
Time Dependent effects cannot reconcile these measurements
(Izmodenov et al. 2005; 2008)



Indicating that some
physics is missing in the models

How Porous is the Heliopause?





Voyager 1

Voyager 2

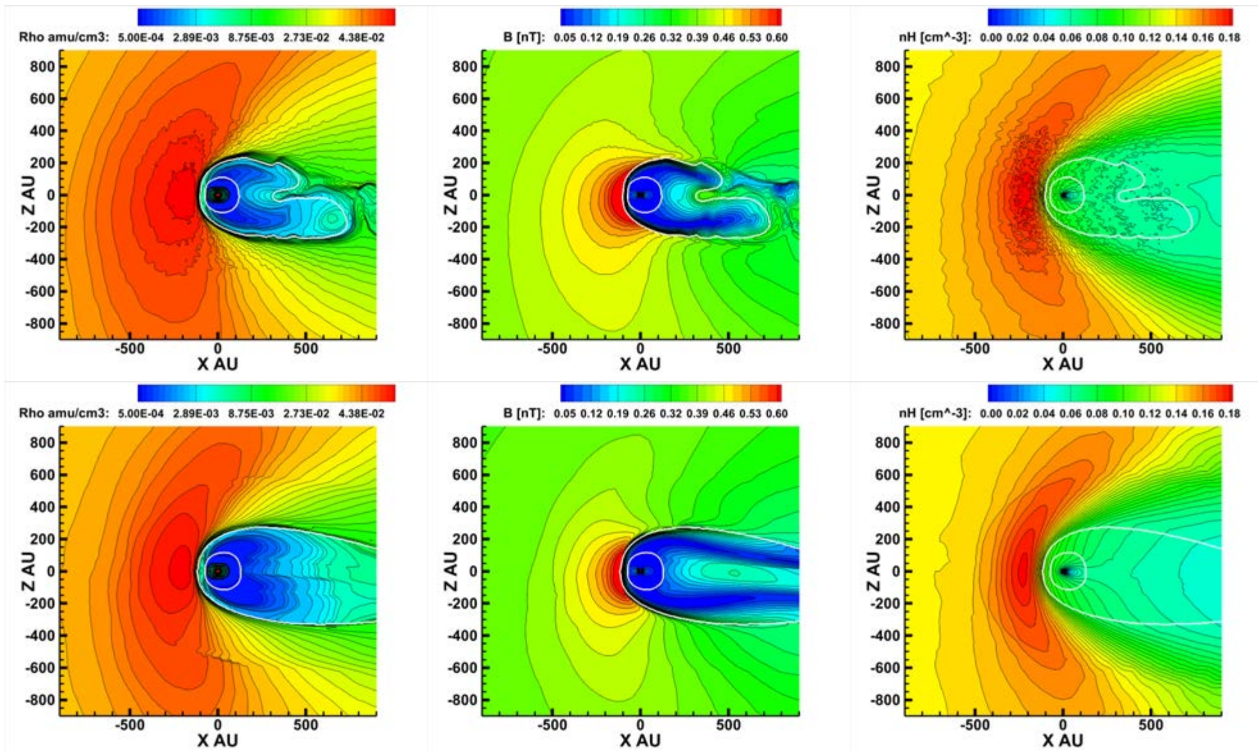
The Properties of the Heliopause are not understood

The crossing of the Heliopause were drastically different at Voyager 1 and 2.

Formation of a Confined HS plasma by the Solar B in Both Models

BU Model

Moscow Model

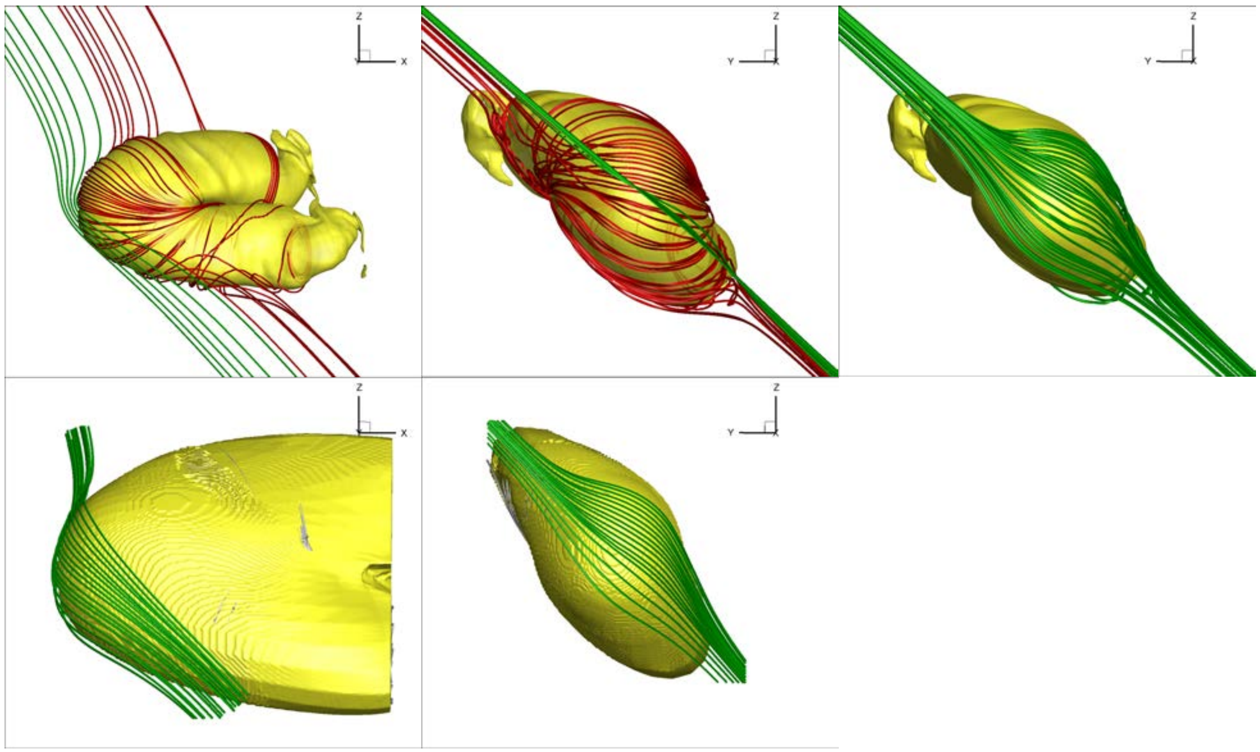


Kornbleuth et al. 2021

Draping of the interstellar magnetic field

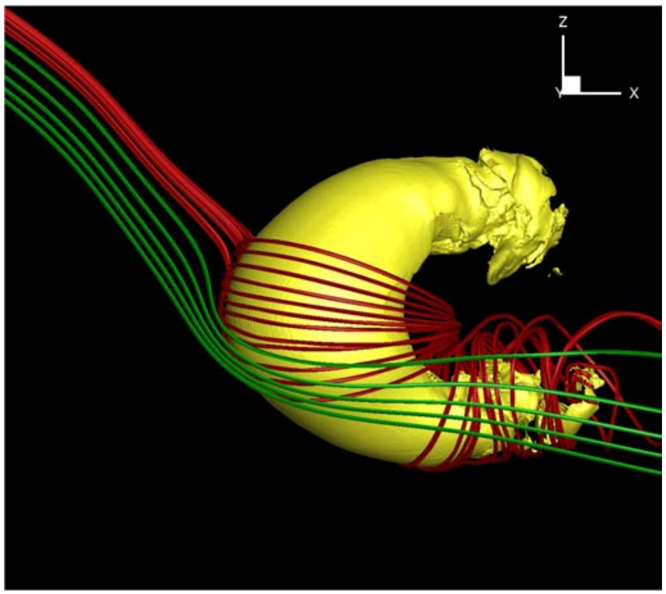
SHIELD/BU

Moscow



Kornbleuth et al. 2021

Reconnection in the flanks predicts no field rotation at the HP At V1 and V2

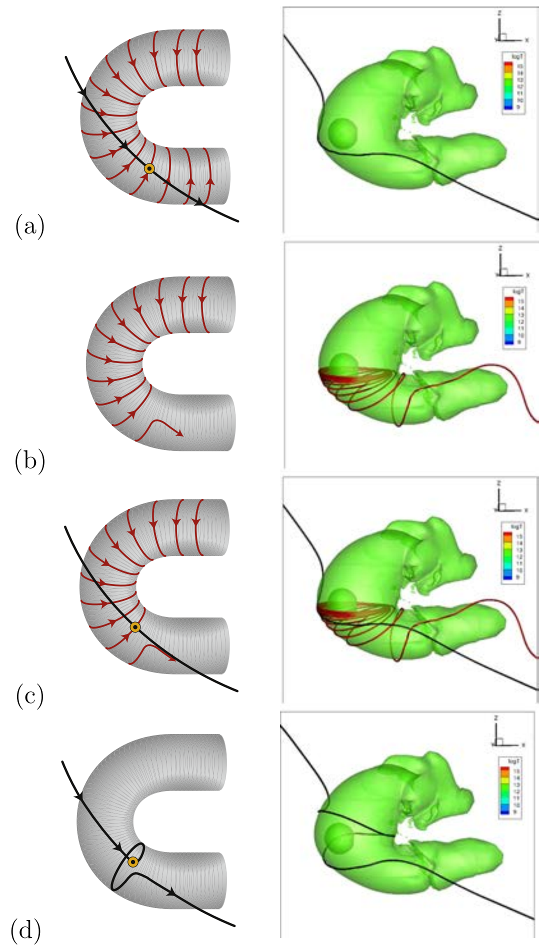


Opher et al. 2017

Two family lines:

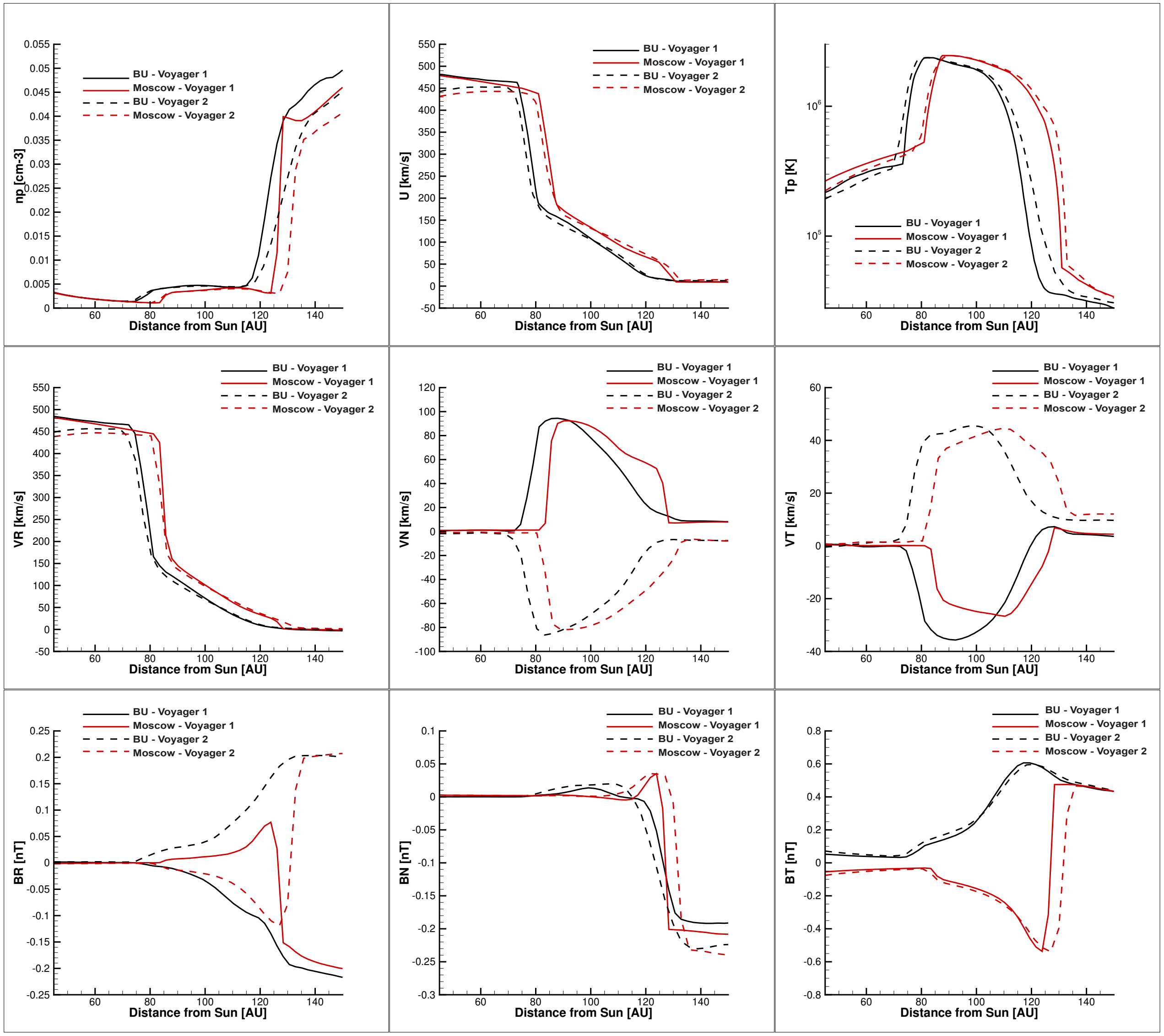
Red: connected to reconnection site in the flanks

Green: rotation towards the BISM



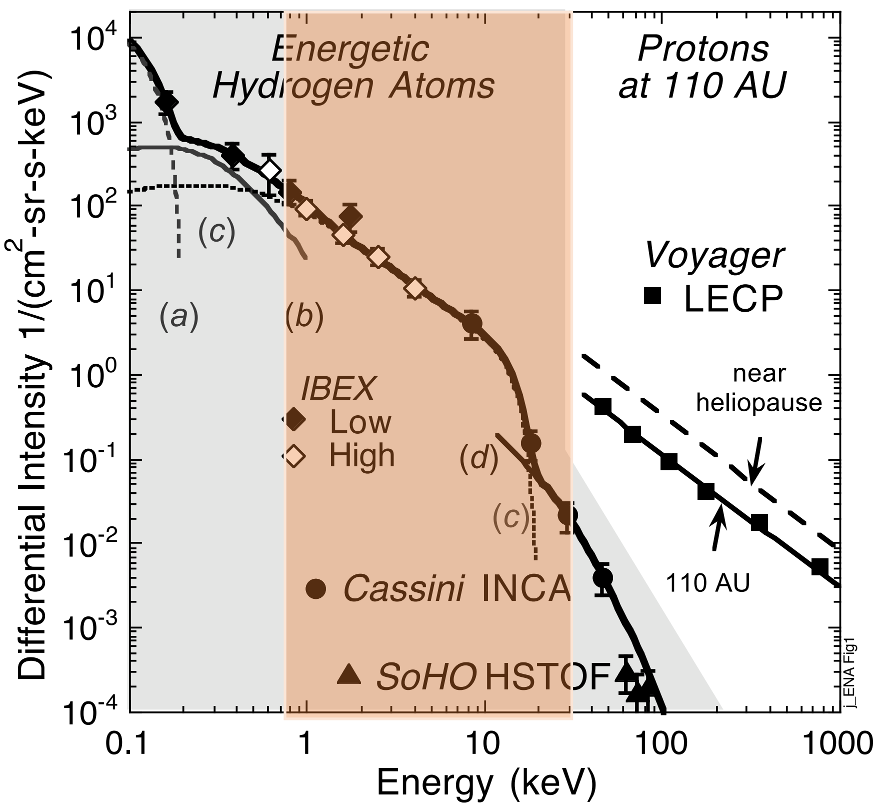
Reconnection Re-Arrange the Interstellar Magnetic Field ahead of the Heliopause to be solar like

Issue is how the field will drape from the HP to the pristine direction and value



Kornbleuth et al. 2021

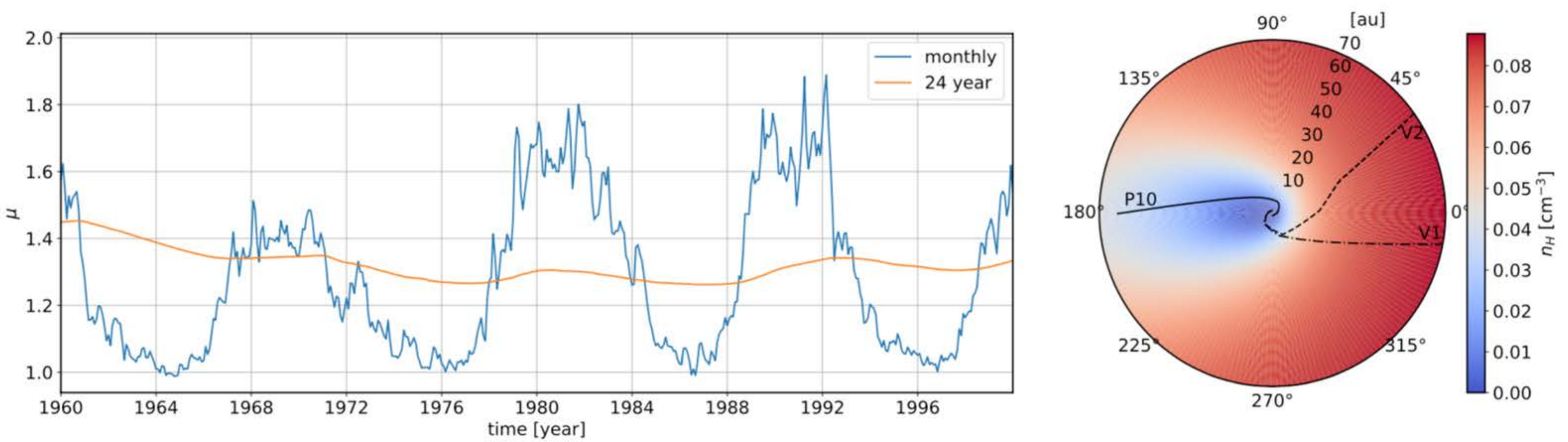
Science Question B:
How do Pick-Up Ions evolve from “cradle to grave”?



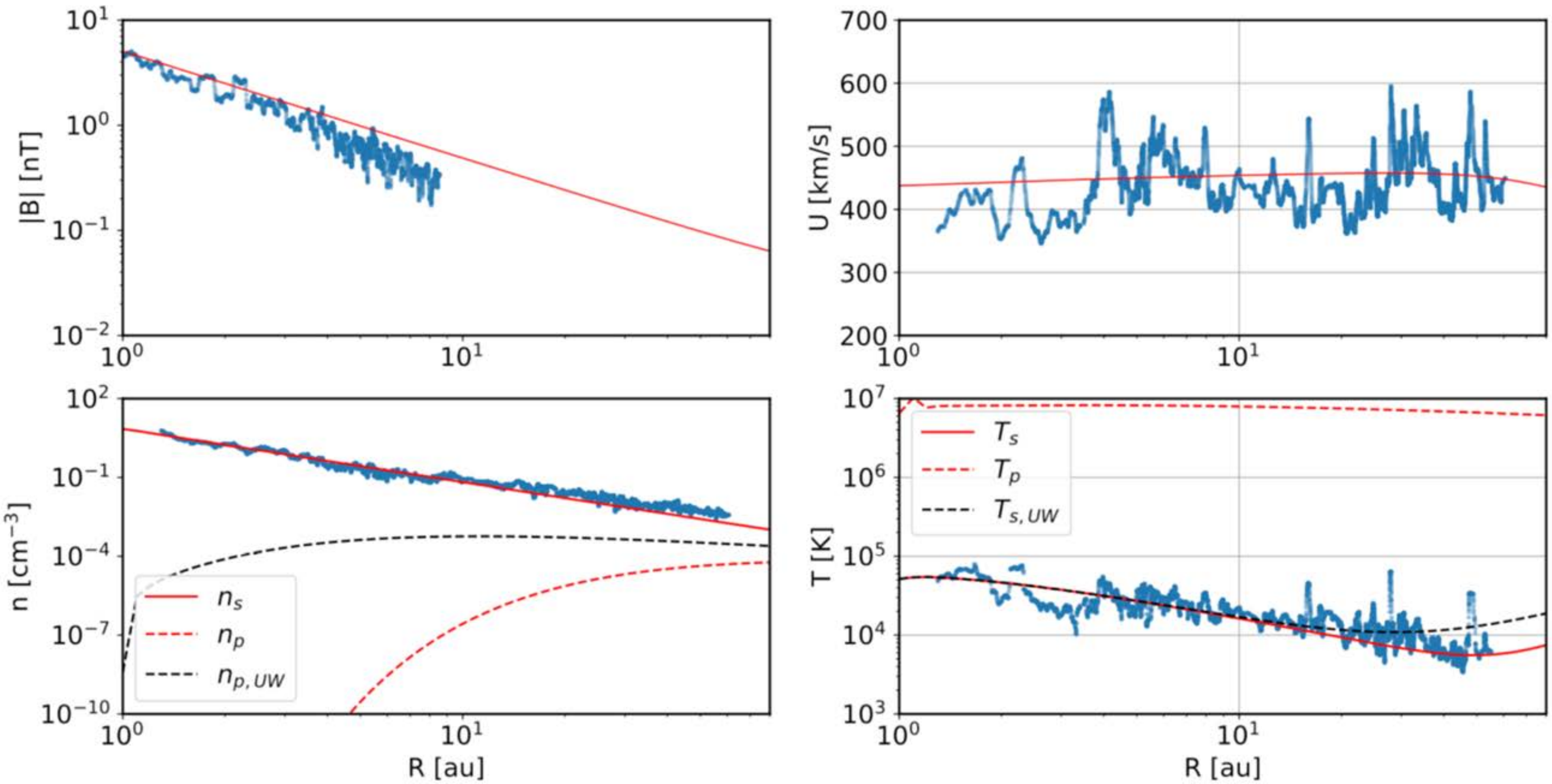
PUIs are particles with energy > ~0.5 keV (hotter than the thermal component of the solar wind)

Voyager is “blind” to PUIs until 28keV

The Downwind Solar Wind: Model Comparison with Pioneer 10 Observations, by M. Nakanotini, G.P. Zank, L. Adhikari, L.-L. Zhao, J. Giacalone, M. Opher, and J.D. Richardson, ApJLetters, 2020



Left panel: Monthly (blue) and 24 year (orange) average of the ratio μ of solar radiation pressure to solar gravity, **right panel:** Hydrogen density distribution and the trajectories of Pioneer 10, Voyager 1 and 2. The H distribution is based on the “hot model” (Wu & Judge 1979; Thomas 1978).

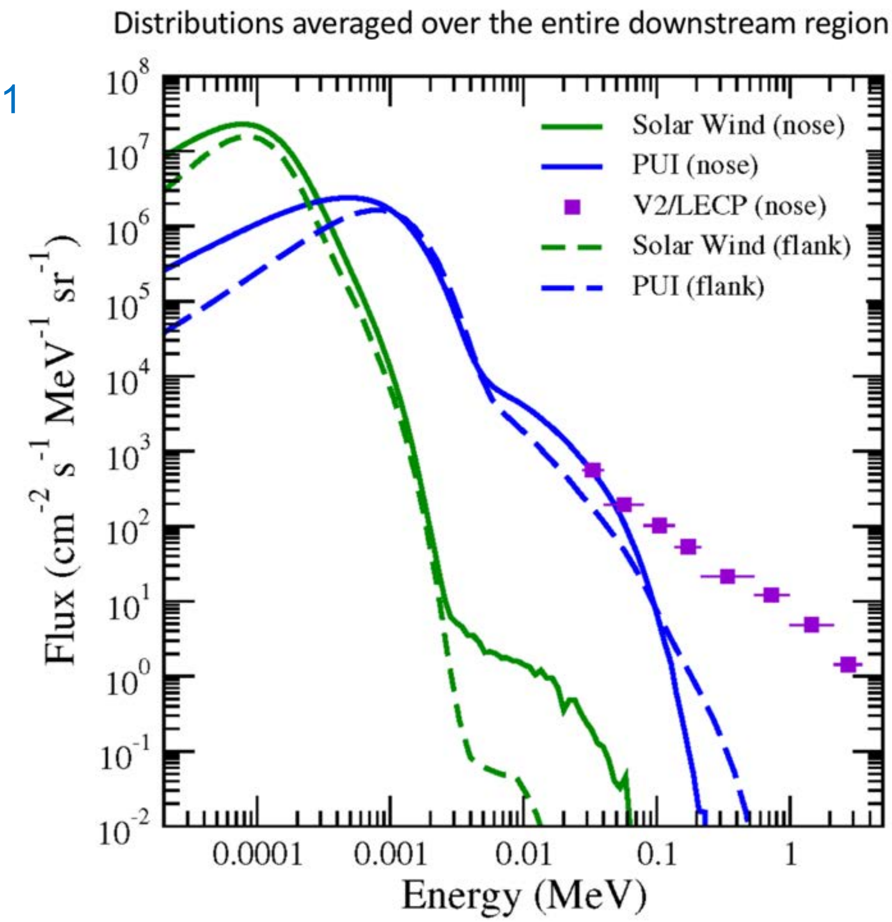


The theoretical model for the downwind solar wind (red line), and Pioneer 10 observations (filled points). **Top left:** the magnitude of the background azimuthal magnetic field, **top right:** the bulk flow speed, **bottom left:** the thermal plasma (solid) and PUI (dashed) number density, and bottom right: the thermal plasma (solid) and PUI (dashed) temperature. Black dashed line is the upwind solar wind obtained from the same model but with uH = 20km/s, θ=0°, and L=7au.

Comparison of spectra at the nose and flank of the termination shock, J. Giacalone (Zank, G., Nakanotani, M., Kota, J., Opher, M., Richardson, J.)

Giacalone et al. 2021

- The flux of the shock-accelerated tail particles (5-40 keV) is very similar in these two locations
- In both cases, the spectrum falls off rapidly above about 50 keV, which is due to the small simulation domain and simulation time.



Science Question C:
How does the heliosphere interacts with Interstellar Medium?

Magnetic Trapping of GCRs in Outer Heliosheath

Florinski, V., Chanbari, K., Kleiman, J. Opher, M., Giacalone, Kota, Cummings

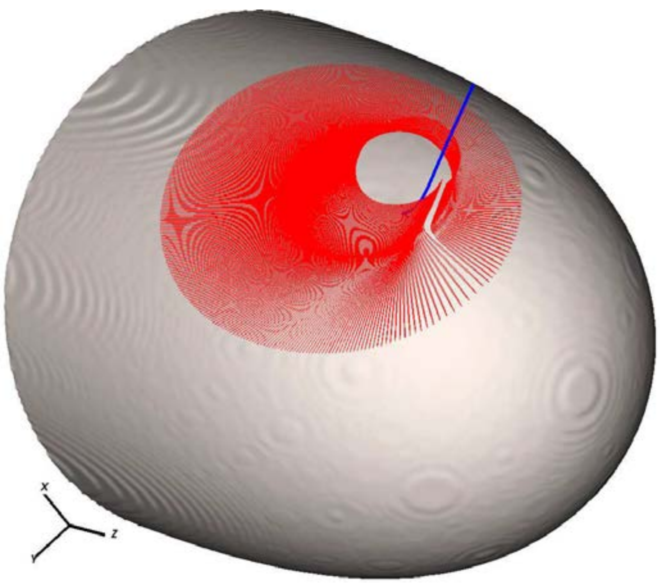


Figure 4. One complete orbit of a 1 GeV cosmic-ray proton placed in a magnetic trap with an initial pitch angle of 80° (red line). The trajectory integration time was 3950 days. A single magnetic field line "ending" at the null point is shown in blue. The surface is the heliopause is light gray in color.

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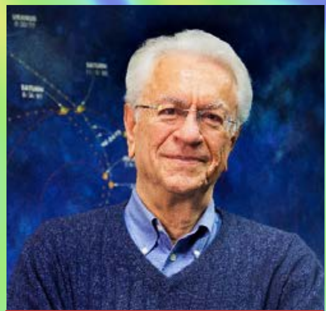
NASA Headquarters



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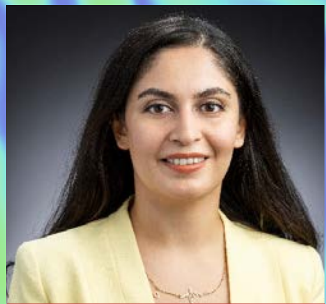

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